Preface

Time-delays inherently occur in physical, industrial and engineering systems as a consequence of limitations in information processing time, data transmission among various parts of the system, arising as feedback delays in the control loops, etc. Time-delays have a considerable influence on the stability of the dynamical systems leading to instability and even degradation in the performances of the systems. So, in order to understand the behaviour of the systems properly, it is important to include time-delays in the mathematical representation of the dynamical systems that can lead to accurate stability analysis and consequently proper controller designs. The mathematical representation of dynamical system with time-delay information embedded in it leads to a model which is referred as delay-differential equations (DDE) or functional differential equations (FDE). In this thesis, we consider the problem of stability analysis and controller synthesis of linear retarded time-delay systems. The motivation behind such study and investigation is the presence of time-delay in wide variety of engineering systems.

The book deals with the problem of stability analysis and controller synthesis of linear and Fuzzy time-delay system. The first four chapters of the book discuss stability and stabilization of linear time-delay system based on Lyapunov–Krasovskii (LK) functional approach in a linear matrix inequality (LMI) framework. The proposed and existing delay-dependent stability as well as robust stability conditions brings out the fact that the conservatism in the analysis and synthesis of such problems lies in the selection of appropriate LK functional approach and subsequently use suitable tighter bounding inequality to yield a quadratic stability condition that can be recast in the LMI framework. The conditions are provided with emphasis on (i) achieving less conservative delay upper bound estimate compared to the existing criteria and (ii) use of lesser free matrix variables in LMIs such that derived conditions obtained are computationally efficient when solved using LMI toolbox of MATLAB. Next, the problem of controller synthesis using state-feedback control law for nominal and uncertain time-delay systems is discussed in both LMI and nonlinear LMI (NLMI) frameworks. As NLMI condition is not a convex problem, it is solved as a linear minimization problem called cone complementarity algorithm, whereas LMI condition is solved

along with multi-objective optimization algorithm, with the following objectives in mind (i) to achieve less conservative delay upper bound and (ii) to design controller that stabilizes the system with less control effort for a given delay value. In sequel, an application to load-frequency control (LFC) problem for a two-area interconnected power system with communication delay is presented here. Another variant of controller synthesis problems for nominal as well as uncertain linear time-delay system with actuator saturation is discussed here that highlights that improved proposing a new delay-dependent local (regional) stabilization criterion leads to improved estimation of delay range as well as gives enhanced domain of attraction (DOA). The controller design takes into account the saturation function by its equivalent linear approximations with two different design techniques, namely (i) polytopic and (ii) sector nonlinearities. The last chapter of the book deals about stability analysis and controller synthesis of Fuzzy T-S time-delay system in an LMI framework. The advantage of using Fuzzy T-S modelling approach is that, for any given nonlinear system if operating points are well defined or known by the user, then the given nonlinear system can be universally approximated as a piecewise linear model using Fuzzy T-S models. Once they are converted into linearized models, then the existing analysis and control methods for linear time-delay system can be readily used for solving the system.

This book is intended for the readers who are naive in the field of time-delay control system as it provides extensive review of research in this area and also discusses systematically the development of various integral inequalities and LK functionals that lead to the improvement of delay bound results. This book can be used as a text for teaching time-delay systems and control of postgraduate students in control engineering as well as used by advanced researchers involved in analysis and synthesis of such systems. The contents of the book have been used to teach Ph.D. students of National Institute of Technology, Silchar, India, for the course fractional order and time-delay systems and control. Furthermore, some MATLAB codes are given at the Appendix for the beginners to acquaint them with the solution of LMI conditions.

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