Abstract

The present thesis is concerned with development and study of methods for reduced order modeling and controller design of linear discrete-time systems modeled in the delta domain.

Traditionally discrete-time sampled data systems are represented using shift-operator parameterization. Such parameterizations are not suitable at fast sampling rates. An alternative parameterization using the so-called delta operator maintains a close correspondence to its continuous-time counterpart at fast sampling rate. Using delta operator parameterization it is possible to unify both discrete-time and continuous-time theory. In addition, this parameterization possesses certain numerical advantages compared to the shift-operator representation.

A unified framework is developed to present new methods for obtaining reduced-order models for high-order discrete-time and continuous-time linear time-invariant dynamic systems, and to apply the model order reduction philosophy to design controllers for such systems. In this work, the main emphasis is on developing frequency-domain techniques for the above two problems. Padé-type methods are developed for reduced-order modeling and controller design in delta domain. The methods developed mainly use the transfer function description and are applicable to single-input single-output (SISO) as well as multiple-input multiple-output (MIMO) systems.

The mathematical procedure of system modeling often leads to a comprehensive description of a process in the form of high-order transfer function or state-space model. It is often desirable, and sometimes necessary, to seek the possibility of finding a reduced-order representation of the original high-order system description. The work on reduced order modeling in the thesis develops some approaches and techniques for effectively obtaining a reduced-order model of a given high-order system based on matching Delta Time Moments (DTM) and Delta Markov Parameters (DMP). In delta domain, these two new parameters are developed, and their analogies with s-domain time moments and Markov parameters are established. At fast sampling limit, DTMs and DMPs respectively converge to the corresponding time moments and Markov parameters of the continuous-time system leading to a unified treatment for

discrete-time and continuous-time reduction methods simultaneously. A more generalized pair of parameters called the Generalized Delta Time Moment (GDTM) and the Generalized Delta Markov Parameter (GDMP) are defined to overcome the occasional stability preservation problem of Padé-like methods and used in the context of reduced order modeling of SISO systems. An approximate frequency fitting (AFF) method is developed in the delta domain which is used to obtain reduced order models for SISO systems.

Many systems that arise in practice are multi-input multi-output (MIMO) in nature and are of high order. The complexity involved in the analysis of such high-order systems and computational considerations make necessary the determination and use of reduced-order MIMO models which are good approximations of the original system. The DTM, DMP, DGTM, DGMP and AFF based methods are successfully employed to obtain satisfactory reduced order models for MIMO systems.

A novel methodology is developed to design controllers for a wide variety of dynamic plants and processes in the delta domain. The concept of approximate model matching is adopted to provide the framework for this development. This allows simple and direct specification of desired closed-loop characteristics. The specifications considered in the present work are: the standard classical requirements like settling time, rise time, allowable peak overshoot in the response to a unit step in the time domain; gain and phase margins, bandwidth etc., in the frequency domain. The first step to begin the design procedure is the selection of a reference model transfer function that represents the desired closed-loop system requirements. A controller that uses output feedback in the standard unity-feedback configuration is then designed such that it results in a closed-loop system response that closely matches that of the reference transfer function.

Given a suitable, implementable reference transfer function, the method directly yields a low order practical dynamic controller without requiring either plant order reduction or controller order reduction. Selection of an appropriate reference model transfer function makes the method applicable to unstable plants, non-minimum-phase plants, and processes involving time delay. The design is carried out by using DTM, GDTM and AFF parameters. The methodology is extended to encompass the problem of controller design for multi-input multi-output systems.

Several numerical examples are provided to illustrate each method. These examples include some practical system models taken from the literature. The examples clearly illustrate the usefulness of the methods developed in the thesis for practical problems and demonstrate that the proposed methods offer a viable and often attractive alternative to some prevalent methods.