State Feedback Control for Structured Descriptor Systems : A Graph Theoretic Approach

A THESIS

submitted by

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“Imagination is more important than knowledge”.

“If we knew what it was we were doing, it would not be called research, would it ?”

– *Albert Einstein*

The dedication of this thesis is split nine ways:

To my Grandfather,

To my Grandmother,

To my Dad,

To my Mom,

To my Brother,

To my extended family of Friends,

To my Roommates,

To my Teachers,

And,

To all those who stuck with me until the very end.

Declaration

I hereby declare that the entire work embodied in this thesis is the result of the investigations carried out by me in the **School of Computing and Electrical Engineering, Indian Institute of Technology Mandi**, under the supervision of **Dr. Subashish Datta**. This work has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made wherever the work described is based on finding of other investigators. In addition, I certify that no part of this work will, in future, be used for submission in my name, for the award of any other degree at any university.

Place: Mandi **Harsha Mathur**

Date:

Thesis Certificate

This is to certify that the thesis titled **"State Feedback Control for Structured Descriptor Systems: A Graph Theoretic Approach"**, submitted by **Harsha Mathur**, at the Indian Institute of Technology Mandi for the award of Master of Science (by research) is a bonafide record of the research work carried out by her under my supervision. The content of this thesis, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

Dr. Subashish Datta

(Guide)

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ABSTRACT

Many physical systems, such as electrical networks, micro-grids, space vehicles and constrained mechanical systems are often modeled appropriately by combination of differential and algebraic equations and the resulting model is known as *Differential and Algebraic (DAE)* model. The dynamic behavior of energy storage elements in the system is described using differential equations whereas the algebraic equations arise to satisfy conservation laws and boundary conditions. Such systems are known as *Descriptor Systems*. Often in practical applications, it is observed that the system matrices in these *DAE* models capture some inherent structure,that is, the entries in the system matrices are either a fixed zero/one or a free parameter and such *Structured Descriptor Systems* can naturally be represented by directed graphs. Graph theoretic approach is useful since it is possible to study the structural properties of the system without depending on the numerical parameters. State feedback control or pole placement has been widely used in industries since several decades. With the help of state feedback control, the dynamics of a controllable plant can be modified by assigning the closed loop poles at arbitrary locations of the complex plane. Since state feedback controllers are more reliable and less complex hence, it is easy to implement them in many practical applications. In this thesis, the problem of designing a static state feedback control for a LTI structured descriptor systems is considered. As only the structure of system is taken into consideration, the designed controller is robust to parametric perturbations.

The preliminaries on descriptor systems and structured systems are discussed. The digraph representation for open loop and closed loop structured descriptor systems is defined and thereafter the problem is formulated. Corresponding to the closed loop system, a square matrix is defined and a result is proposed to compute the coefficients of the closed loop characteristic polynomial using graphs. The adjoint corresponding to the open loop system matrix is computed using graphs. A relation between the adjoint of open loop system matrix and the input to the system is derived which is used to compute the feedback gain vector. A graph theoretic sufficient condition is proposed which is based on the existence of spanning cycle family in the resulting digraph. The effectiveness of the proposed approach is verified

by taking numerical example.

Contents