Summary of Research

Title: Synthesis Methods for Robust Passification and Control

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Report Duration: 06/00-11/00
Preface

This report provides a concluding summary of the research work performed over the duration 6/00-11/00 for the co-operative research agreement NCC-1-348 between NASA Langley Research Center and Kansas State University. As the P.I., Dr. Atul G. Kelkar, will be moving to Iowa State University effective January 2001 the remainder of the work will be continued at the new institution.

1 Executive Summary

The research effort under this cooperative agreement has been essentially the continuation of the work from previous grants. The ongoing work has primarily focused on developing passivity-based control techniques for Linear Time-Invariant (LTI) systems. During this period, there has been a significant progress made in the area of passivity-based control of LTI systems and some preliminary results have also been obtained for nonlinear systems, as well.

The prior work has addressed optimal control design for inherently passive as well as non-passive linear systems. For exploiting the robustness characteristics of passivity-based controllers the passification methodology was developed for LTI systems that are not inherently passive. Various methods of passification were first proposed in [4] and further developed in [5], [8], and [10]. In [7], the robustness of passification was addressed for multi-input multi-output (MIMO) systems for certain classes of uncertainties using frequency-domain methods. For MIMO systems, a state-space approach using Linear Matrix Inequality (LMI)-based formulation was presented in [13] for passification of non-passive LTI systems. In [8], an LMI-based robust passification technique was presented for systems with redundant actuators and sensors. The redundancy in actuators and sensors was used effectively for robust passification using the LMI formulation. The passification was designed to be robust to an interval-type uncertainties in system parameters. In [?], the passification techniques were used to design a robust controller for Benchmark Active Control Technology wing under parametric uncertainties. The results on passive nonlinear systems, however, are very limited to date. Our recent work in this area was presented in [7] wherein some stability results were obtained for passive nonlinear systems that are affine in control.
The passification methodology was validated experimentally on two different real-life test articles, namely, flexible link with piezo actuator [11] and 1-D acoustic duct pk01-j. It was demonstrated that the passivity-based controllers can provide robust stability for unmodeled dynamics and parametric uncertainties even for nonminimum systems such as these using robust passification techniques.

Several publications and conference presentations resulted from this ongoing research. The list of publications and presentations is given below.

**List of Publications**


*Control of Nonlinear Multibody Flexible Space Structures*, volume 221 of *Lecture Notes in Control and Information Sciences*.

Springer-Verlag, August 1996.


Global stabilization of flexible multibody spacecraft using quaternion-based nonlinear control law.


On longitudinal control of high speed aircraft in the presence of aeroelastic modes.


Robust control of a class of passive nonlinear systems.


Inner loop control of supersonic aircraft in the presence of aeroelastic modes.


Robust passification and control of non-passive systems.

Asymptotic stability of interconnected passive non-linear systems.

Robust passification via optimal sensor blending and control allocation.

Control of bact wing via robust passification.

Synthesis of lq-optimal constant-gain positive-real controllers.
*Control and Intelligent Systems (to appear), 2000.*

Modeling and control of nonlinear flexible robots.

Control of piezo-actuated flexible link.
*Control and Intelligent Systems (submitted), 2000.*

Lmi-based passification for control of nonpassive systems.
*Automatica (to be submitted).*

Modeling and control of Acoustic Ducts.

Inner loop control of supersonic aircraft in the presence of aeroelastic modes.


Trajectory tracking of multibody spacecraft.

Globally stable maneuvers of flexible space robots.

Robust control of non-passive systems via passification.

Passivity-based control of elastic systems.

On passivity-based control of flexible multibody nonlinear systems.

Robust passification and control of non-passive systems.
Passification via dynamic feedback compensation.

Robust passification via optimal sensor blending and control allocation.

Synthesis of optimal constant-gain positive real controllers.

A concurrent design methodology for control of slewing flexible link using piezo-actuators and sensors.

Robust control of uncertain systems via norm-bounded lqg-type controllers.

Lmi-based passification for control of non-passive systems.

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*2000 American Control Conference (presented as an invited paper)*, Chicago, IL, June 28-30 2000.