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MULTIVARIABLE AND DISTRIBUTED CONTROL OF NONLINEAR CHEMICAL PROCESSES USING ADAPTIVE METHODS

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Abstract:

In this work we studied the application of adaptive learning and optimization to chemical process control. The work covered theory as well as practical applications of adaptive and nonlinear control, including multivariable periodic control. The main findings were:

1. Linear adaptive control systems may display chaotic behavior. The chaos has small amplitude if the algorithm is properly implemented.

2. Stability theory for nonlinear adaptive control has been developed.

3. Experimental evaluation of predictive control was performed.

4. A theory for periodic control and adaptive periodic control of chemical processes was developed.

Detailed reports of progress can be found in the listed publications at the end of this report.

Contents:

NOTICE

Introduction:

Most Chemical Processes have complex nonlinear dynamics, strong interactions between operating variables and are difficult to model. Currently these processes are almost exclusively controlled using simple linear theory in the form of decentralized PI-regulators, and occasionally derivative and feed forward control is used. Although most chemical processes are designed to be self-stabilizing and *can* be controlled using such simple devices, this may not be the best alternative and it has been shown that large savings can be incurred by using more advanced control theory.

In this research we focussed on developing theory as well as practical algorithms for advanced control methods based on adaptation. By adaptation we imply that the algorithm is designed to learn and change its characteristics depending on the current operating conditions and environment. In particular we focused the research on developing theory for the use of multivariable predictive algorithms.

Research Results:

Progress was made in several areas. Detailed discussions are given in the papers and reports referenced below. Here we give brief descriptions of project areas:

1. Application of Multivariable Adaptive Control.

   During the first stages of this research we applied the extended horizon adaptive controller to the distillation column in our laboratory to investigate the feasibility of multivariable adaptive control. While the results were encouraging, it became clear that there were numerous short comings in the available theory for adaptive control. In particular, it became evident that adaptive control systems may display small amplitude chaos and intermittent bursting.

2. Chaos in adaptive control systems.

   The aim of this study was to investigate how instability manifests itself in adaptive systems. We focussed on two issues, the first concerned the drift and burst problems, the second concerned the small amplitude chaotic problem. We were successful in proving the existence of chaotic attractors and ergodicity.

3. On line optimization.

   Two nonlinear problems were investigated. The first concerned the optimization of a continuous bio-reactor. Experiments were performed and the results were encouraging. In the second problem we investigated the feasibility of developing adaptive optimizing controllers for periodic systems. Some success was experienced, however, numerous problems were encountered and it was decided that research of this type is premature in the sense that it is unlikely that this theory will find its way into industrial application in the near future. Some progress was made in a parameter sensitivity study.

4. Identification.

We also developed a method for identification of continuous time transfer functions based on the modulating function approach. This research was particularly fruitful and it will lead to the development of a new approach to predictive control based on the use of Laguerre functions. This research formed the foundation for a more applied research program which was funded by Shell Development Company and is now being completed.

5. Nonlinear Adaptive Control.

We continued developing the idea of using static elements to decouple/linearize nonlinear chemical processes. This idea appeared to have some merit and improved results were obtained in simulation and pilot plant experiments. A related idea (Generic Model Control) has recently surfaced in the literature and numerous industrial examples show that the approach we investigated can yield improved control for a wide range of chemical processes.

Summary:

We experienced great progress in the area of adaptive control during the period 1984-1988. During this period we had at any given time 4-5 Ph.D. or M.S. students working on adaptive control related topics. Several theoretical breakthroughs were made and better algorithms for on-line adaptive control, nonlinear control and optimization were developed. The publications of many of these results were delayed, due to a number of difficult theoretical issues that had to be sorted out. These have all been concluded and the key results have appeared or are due to appear shortly in the open literature. During this key period of time we had significant support from the U.S. Department of Energy and the National Science Foundation. Papers and reports where DOE is recognized as a key funding agent are listed below.

During the funding period the PI devoted approximately 10% of his time to this project during the academic year and 50% during the summer months.

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