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December 1982

Institute for

Electronic Science

TEXAS TECH UNIVERSITY
Lubbock, Texas 79409
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<tr>
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<tbody>
<tr>
<td>R. Saeks, L.R. Hunt, J. Murray J. Walkup, T. Krile and T.G. Newman</td>
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<th><strong>10. PROGRAM ELEMENT, PROJECT, TASK AREA &amp; WORK UNIT NUMBERS</strong></th>
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<th><strong>19. KEY WORDS (Continue on reverse side if necessary and identify by block number)</strong></th>
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with abstracts of published and pending papers. This report also includes lists of all grants and contracts administered by JSEP personnel of grants and contracts in the Department of Electrical Engineering and Mathematics, and of publications prepared by JSEP investigators.
REVIEW OF RESEARCH
under the
JOINT SERVICES ELECTRONICS PROGRAM
at the
INSTITUTE FOR ELECTRONIC SCIENCE
TEXAS TECH UNIVERSITY

Period Covered
December 1981 - December 1982
Lubbock, Texas 79409
Abstract

This report represents the sixth year of research performed under the auspices of the Joint Services Electronics Program at Texas Tech University. The program is in the area of information electronics and includes researchers from Electrical Engineering and Mathematics. Specific work units deal with Feedback System Design, Nonlinear Control, Nonlinear Fault Analysis, Image Processing, and Pointing and Tracking.

A summary of the research performed during 1982 for each work unit is presented. In addition, we have provided a list of publications and activities together with abstracts of published and pending papers. This report also includes lists of all grants and contracts administered by JSEP personnel, of grants and contracts in the Department of Electrical Engineering and Mathematics, and of publications prepared by JSEP investigators.
Contents

Significant Accomplishments Report........................................... 1

1. Feedback System Design, R. Saeks........................................... 5
   *Abstracts of Publications.................................................. 7

2. Nonlinear Control, L.R. Hunt................................................ 19
   *Abstracts of Publications.................................................. 23

3. Nonlinear Fault Analysis, R. Saeks........................................ 55
   *Abstracts of Publications.................................................. 57

4. Multidimensional System Theory, J. Murray.............................. 69
   *Abstracts of Publications.................................................. 71

5. Detection and Estimation in Imagery, J. Walkup........................ 87
   *Abstracts of Publications.................................................. 89

6. Pointing and Tracking, T.G. Newman...................................... 93
   *Abstracts of Publications.................................................. 97

Grants and Contracts Administered by JSEP Personnel................. 101

Grants and Contracts in Electrical Engineering..................... 103

Grants and Contracts in Mathematics.................................... 107

Publications for JSEP Personnel........................................... 109

*Publications are available on request from Dr. L.R. Hunt,
Director, Joint Services Electronics Program, Mathematics
Department, Texas Tech University, Lubbock, TX 79409.
Significant Accomplishments Report:

A. Nonlinear Control

During the past year, Professor Hunt, together with R. Su of Texas Tech, George Meyer of NASA Ames and Hunt's students, have extended their results concerning transformations of nonlinear systems. Previous research emphasized necessary and sufficient conditions that a multi-input nonlinear system be transformable to a controllable linear system. Moreover, a formal procedure for constructing such transformations was presented. The proper mathematics for the development of our theory is differential geometry, which is as natural for nonlinear systems as linear algebra is for linear systems. Meyer is applying our transformation results to his totally automatic flight control system (TAFCOS). Simulation results for having a UH-IH helicopter fly a prescribed trajectory are impressive, and actual flight tests are presently underway.

The transformation theory has been extended to time varying systems. That is, necessary and sufficient conditions that a time varying nonlinear system be transformable to a controllable time-invariant linear system have been presented.

If a nonlinear system cannot be transformed to a linear system, it still may be possible to simplify the system. We have provided a technique to find coordinates in state and control variables so that only the intrinsic nonlinearities of the system remain, and those nonlinearities due to unfortunate choices of coordinates are removed.

Another major accomplishment is the proof that the design scheme (for nonlinear systems which are transformable to linear systems) in
Meyer's TACFOS is robust. We show that if the linear system is stabilized, then the equivalent nonlinear system is stabilized as well as all "nearby" systems. In this way Lyapunov functions for the nonlinear systems are found.

As mentioned previously, there is a formal method for constructing a transformation from a nonlinear system to a linear system. Numerical and symbolic (using the MIT MACSYMA program) procedures for building transformations have been developed.

B. Detection and Estimation in Imagery

During the 1982 year, Dr. John F. Walkup with his colleagues and students made considerable progress in research on detection and estimation in imagery. Listed below are the significant accomplishments of this area.

A technique was developed for recovering image signal information from signal-dependent noise when the noise dominates the signal term. Both Gaussian (film grain noise) and Poisson (shot noise) models were considered, with dramatic results obtained.

The use of spatially adaptive local minimum mean square error point estimators were found to be superior to global mmse estimators for image restoration in signal-dependent noise.

A multi-parameter MAP estimator based on a Markovian image covariance model was derived and found to have excellent noise suppression properties and good edge fidelity when tested on real imagery.

A transformation to convert signal dependent Gaussian image noise to signal-independent Gaussian noise was derived. Wiener filtering techniques were applied to the transformed image followed by an inverse transformation to restore the degraded image.
Both robust point-estimators and robust multi-parameter estimators were derived for operation in Gaussian signal-dependent noise. These estimators are designed to be robust with respect to deviations from the assumed signal or noise statistics, and have been tested with various images.
Title of Investigation: Feedback System Design

Senior Investigator: Richard Saeks  Telephone: (806)-742-3528

JSEP Funds: $27,225

Other Funds:

Total Number of Professionals: PI 1 (1 mo.)  RA 1 (1/2 time)

Summary:

Our program during the past year under this project has been directed primarily towards the development of a frequency domain pole placement theory formulated in the context of the YBJ (Youla, Bongiorno and Jabr) design philosophy. Here, one is given a plant, p(s), around which one desires to design a feedback system which is stable and simultaneously places the poles of the resultant input-output gain at the zeros of a prescribed Hurwitz polynomial, q(s). Surprisingly, in the single variate case the existence of such a feedback system is characterized by the simple numerical inequality

$$\text{o}(q) > \text{r}(p) + \delta$$

where o(q) is the order of q(s), r(p) is the total number of (closed) right half-plane poles and zeros of the plant (including -\infty) and \delta is either 1 or 0.

In the multivariate case we have obtained partial results for the case of a stable square plant, P(s). In this case separate, necessary and sufficient conditions have been obtained which, unfortunately, do not
coincide except in the single variate case. As before, however, these conditions take the form of simple numerical inequalities.

In other related areas we have developed an abstract algebraic geometric theory for the simultaneous design problem and continued our work on the n-plant \( n \geq 3 \) simultaneous design problem. Furthermore, we have initiated a study of the minimal degree compensator problem, i.e., the problem of designing a minimal degree compensator which achieves a prescribed set of design specifications.

7. **Publications and Activities**

A. **Refereed Journal Articles**


B. **Conference Papers and Abstract**


C. **Preprints**


D. **Dissertations and Theses**


E. **Conferences and Symposia**

ABSTRACT

THE FEEDBACK SYSTEM DESIGN:
The Single-Variate Case - Part I

R. Saeks, J. Murray, O. Chua,
C. Karmokolias and A. Iyer
FEEDBACK SYSTEM DESIGN:  
The Single-Variate Case - Part I

ABSTRACT

A recently developed algebraic approach to the feedback system design problem is reviewed via the derivation of the theory in the single-variate case. This allows the simple algebraic nature of the theory to be brought to the fore while simultaneously minimizing the complexities of the presentation. Rather than simply giving a single solution to the prescribed design problem we endeavor to give a complete parameterization of the set of compensators which meet specifications. Although this might at first seem to complicate our theory it, in fact, opens the way for a sequential approach to the design problem in which one parameterizes the subset of those compensators which meet the second specifications...etc. Specific problems investigated include feedback system stabilization, the tracking and disturbance rejection problem, robust design, transfer function design, pole placement, simultaneous stabilization, and stable stabilization.
ABSTRACT

SIMULTANEOUS DESIGN OF CONTROL SYSTEMS

R. Saeks and J. Murray
SIMULTANEOUS DESIGN OF CONTROL SYSTEMS

Abstract

The problem of designing a feedback controller which stabilizes a number of plants simultaneously is discussed from the fractional representation point of view. An abstract solution of this general simultaneous stabilization problem is presented, and an elementary, explicit criterion is given for the simultaneous stabilizability of two systems. Finally, some examples and counter examples are presented, and some open problems are discussed.
ABSTRACT

FRACTIONAL REPRESENTATION, ALGEBRAIC GEOMETRY, AND THE SIMULTANEOUS STABILIZATION PROBLEM

RICHARD SAEKS AND JOHN MURRAY
Abstract
An explicit relationship between the fractional representation approach
feedback system design and the algebro-geometric approach to system
theory is formulated and used to derive a global solution to the feed-
back system problem. These techniques are then applied to the simul-
taneous stabilization problem, yielding a natural geometric criterion
for a set of plants to be simultaneously stabilized by a single
compensator.
Texas Tech University Institute for Electronic Science
Joint Services Electronics Research Unit: 2

1. **Title of Investigation:** Nonlinear Control

2. **Senior Investigator:** L.R. Hunt **Telephone:** (806) 742-1427

3. **JSEP Funds:** $27,225.

4. **Other Funds:**

5. **Total number of Professionals:** PI 2(1 mo.) RA 1

6. **Summary:**

Many physical systems are modeled by nonlinear mathematics, and these nonlinearities pay a key role in the design of control schemes for the systems. We are interested in methods that incorporate the nonlinearities into the design instead of applying the usual linearizing techniques.

We have proved necessary and sufficient conditions that a nonlinear system be exactly transformable to a controllable linear system. In other words, there are certain nonlinearities that exist because of unfortunate choices of state and control coordinates and that can be removed by using a transformation to the correct variables: This is true for both time-invariant and time-varying nonlinear systems. For general nonlinear systems we have provided a technique to simplify the system by eliminating those nonlinearities that are not intrinsic to the system. This is a generalization of our theory for transforming nonlinear systems to linear systems.

If a system is transformable to a linear system, then the controller is designed on the linear system and mapped back to the nonlinear one.
This is George Meyer's design strategy, which we have shown to be robust. By stabilizing the linear system we also stabilize the nonlinear system and all "nearby" systems. Moreover, Lyapunov functions for the nonlinear system can be found by this method, and these can be used in sensitivity analysis.

An important application of our theory is to automatic flight control for vertical and short take off aircraft. For example, our mathematical model of the UH-IH helicopter is transformable to a controllable linear system. This fact is used (on line) to have the helicopter fly a prescribed trajectory.

7. Publications and Activities

A. Refereed Journal Articles


B. Conference Papers and Abstracts


C. Preprints


D. Dissertations and Theses


E. Conferences and Symposia


ABSTRACT

n-DIMENSIONAL CONTROLLABILITY WITH (n-1) CONTROLS

Louis R. Hunt
n-Dimensional Controllability with (n-1) Controls

Louis R. Hunt

Abstract

Let $M$ be a connected real-analytic n-dimensional manifold, $f, g_1, \ldots, g_{n-1}$ be complete real-analytic vector fields on $M$ which are linearly independent at some point of $M$, and $u_1, \ldots, u_{n-1}$ be real-valued controls. Consider the controllability of the system

$$x(t) = f(x(t)) + \sum_{i=1}^{n-1} u_i(t) g_i(x(t)).$$

$x(0) = x_0 \in M$.

Necessary and sufficient conditions are given so that this system is controllable on any simply connected domain $D$ contained in $M$ on which $g_1, \ldots, g_{n-1}$ are linearly independent. These conditions depend on the computation of Lie brackets at those points where $f, g_1, \ldots, g_{n-1}$ are linearly dependent.
ABSTRACT

SUFFICIENT CONDITIONS FOR CONTROLLABILITY

Louis R. Hunt
SUFFICIENT CONDITIONS FOR CONTROLLABILITY

Louis R. Hunt

ABSTRACT

The problem is to find sufficient conditions for the system

\[ \dot{x}(t) = f(x(t)) + \sum_{i=1}^{m} u_i(t)g_i(x(t)), \quad x(0) = x_0 \in M \]

to be controllable. Here \( M \) is a connected \( C^\infty \) \( n \)-dimensional manifold, \( f, g_1 \ldots g_m \) are complete \( C^\infty \) vector fields on \( M \), and \( u_1, \ldots, u_m \) are real-valued controls. If \( m = n-1 \), \( M, f, g_1 \ldots g_{n-1} \) are real analytic, \( M \) is simply connected and \( g_1, \ldots, g_{n-1} \) are linearly independent on \( M \), then necessary and sufficient conditions are known. For the case of our \( C^\infty \) system with general \( m \), we assume that the space spanned by the Lie algebra \( L_A \) generated by \( f, g_1, \ldots, g_m \) and successive Lie brackets has constant dimension \( p \) on \( M \) and the algebra \( L'_A \) generated by \( g_1, \ldots, g_m \) and successive Lie brackets has constant dimension \( p' \leq p \) on \( M \). If \( p' = p \), Chow's Theorem implies controllability for a \( p \)-dimensional submanifold of \( M \) containing \( x_0 \). If \( p' < p \), sufficient conditions are found involving the computation of certain Lie brackets at points where the vector field \( f \) is tangent to the integral manifolds of \( L'_A \). Here we assume that every integral manifold of \( L'_A \) contains such a point.
ABSTRACT

CONTROL OF NONLINEAR TIME-VARYING SYSTEMS

L. R. Hunt and Renjeng Su
CONTROL OF NONLINEAR TIME-VARYING SYSTEMS

L. R. Hunt and Renjeng Su

Abstract

Consider the time-varying nonlinear system of the form $\dot{x}(t) = f(x,t) + \sum_{i=1}^{m} u_i(t)g_i(x,t)$, with $f, g_1, \ldots, g_m$ being $C^\infty$ vector fields on $\mathbb{R}^{n+1}$. We give necessary and sufficient conditions for this system to be transformable to a time-invariant controllable linear system. In order to control the nonlinear system, we map to the linear system, choose a desired control there and return to the nonlinear system by the inverse of the transformation.
ABSTRACT

THEORY OF DESIGN USING NONLINEAR TRANSFORMATIONS

Renjeng Su, L. R. Hunt, and George Meyer
THEORY OF DESIGN USING NONLINEAR TRANSFORMATIONS

Renjeng Su, L. R. Hunt, and George Meyer

Abstract

This paper is presenting an overview of the theory of transformations from nonlinear systems to linear systems. Topics covered include (1) necessary and sufficient conditions for transformations to exist, (2) a method of constructing transformations, (3) robustness in design (based on transformation theory) and Lyapunov functions, (4) estimation theory, and (5) the relationship between transformation theory and "nonlinear zeros." Application of these results to automatic flight control is presented in another paper at this session.
ABSTRACT

APPLICATIONS TO AERONAUTICS OF THE THEORY OF TRANSFORMATIONS OF NONLINEAR SYSTEMS

George Meyer, Renjeng Su
and L. R. Hunt
APPLICATIONS TO AERONAUTICS OF THE THEORY OF
TRANSFORMATIONS OF NONLINEAR SYSTEMS

George Meyer, Renjeng Su
and L. R. Hunt

Abstract

We discuss the development of a theory, its application to the
control design of nonlinear systems, and results concerning the use of
this design technique for automatic flight control of aircraft. The
theory examines the transformation of nonlinear systems to linear
systems. We show how to apply this in practice, in particular, the
tracking of linear models by nonlinear plants. Results of manned
simulation are also presented.
ABSTRACT

DESIGN FOR MULTI-INPUT NONLINEAR SYSTEMS

L. R. Hunt, Renjeng Su, and G. Meyer
DESIGN FOR MULTI-INPUT NONLINEAR SYSTEMS

L. R. Hunt, Renjeng Su, and G. Meyer

Abstract

Consider the multi-input nonlinear system

\[ \dot{x}(t) = f(x(t)) + \sum_{i=1}^{m} u_i(t)g_i(x(t)), \]

where \( f, g_1, \ldots, g_m \) are \( C^\infty \) vector fields on some neighborhood of the origin in \( \mathbb{R}^n \) and \( f(0) = 0 \). We present necessary and sufficient conditions for this system to be transformed to a controllable linear system. Our results are constructive and depend upon the solutions of overdetermined systems of partial differential equations. Moreover, we indicate how this theory is applied to build an automatic flight controller for vertical and short takeoff (VSTOL) aircraft. Flight-test simulation results are presented.
ABSTRACT

ROBUSTNESS IN NONLINEAR CONTROL

Renjeng Su, George Meyer and L. R. Hunt
ROBUSTNESS IN NONLINEAR CONTROL

Renjeng Su, George Meyer and L. R. Hunt

Abstract

A new design methodology for nonlinear plants using transformations of nonlinear systems to linear systems is presently being developed. It is the purpose of this paper to show that this design theory is robust. If the linear system is asymptotically stabilized by applying appropriate feedback (a well-known technique), then a control to stabilize the nonlinear plant is easily computed through that part of the inverse transformation involving controls. Most importantly, all nearby plants (in the proper topology) are also asymptotically stabilized using this control. Lyapunov functions for nonlinear systems can be found using this method. A short discussion on the application of this design technique to the automatic flight control of aircraft is presented.
ABSTRACT

GLOBAL TRANSFORMATIONS OF NONLINEAR SYSTEMS

L. R. Hunt, Renjeng Su, and George Meyer
GLOBAL TRANSFORMATIONS OF NONLINEAR SYSTEMS
L. R. Hunt, Renjeng Su, and George Meyer

Abstract
Recent results have established necessary and sufficient conditions for a nonlinear system of the form

\[ \dot{x}(t) = f(x(t)) + u(t)g(x(t)) \]

with \( f(0) = 0 \), to be locally equivalent in a neighborhood of the origin in \( \mathbb{R}^n \) to a controllable linear system. We combine these results with several versions of the global inverse function theorem to prove sufficient conditions for the transformation of a nonlinear system to a linear system. In doing so we introduce a technique for constructing a transformation under the assumptions that \( \{g, [f, g], \ldots, (ad^{n-1} f, g)\} \) span an n-dimensional space and that \( \{g, [f, g], \ldots, (ad^{n-2} f, g)\} \) is an involutive set.
Over the past several years the principal investigator and his students have developed a new self-testing algorithm for nonlinear analog fault diagnosis. With the basic algorithm development work now completed our emphasis in this work unit during the past year has been placed on the extension of the theory to cover a large class of systems; digital, hybrid, etc.; a preliminary investigation into the software engineering problems which must be solved to implement the algorithm in a practical CAT code; and preparatory steps to transition the work into a 6.2 activity.

Specific activities include:

i). The development of a prototype software code for implementing the test algorithm in the case of linear systems. This includes the development of appropriate data structures, the implementation of the numerical algorithms, and the development of a user interface for the code.

ii). An investigation of the applicability of the self-testing algorithm to digital, hybrid and electro-mechanical systems. In the former case we believe that the self-testing algorithm can serve as the basis for a 2nd generation digital test package.
though the algorithm cannot simply be translated verbatim to a digital setting. On the other hand the hybrid and electro-mechanical applications represent natural extrapolations of the analog algorithm in which the present analog simulator is replaced by the appropriate hybrid of electro-mechanical simulator.

iii) A statistical analysis of the effect of "good component" tolerances on the performance of the self-testing algorithm. This employs the prototype test package developed for linear systems in a series of numerical experiments.

VII. Publications and Activities:

A. Refereed Journal Articles


B. Dissertations and Theses


C. Conferences and Symposia


56
ABSTRACT

DATA BASE FOR SYMBOLIC NETWORK ANALYSIS

C.-C. Wu and R. Saeks
DATA BASE FOR SYMBOLIC NETWORK ANALYSIS

C.-C. Wu and R. Saeks

Abstract

A data base for generating the symbolic transfer functions for a linear electronic circuit is formulated and an appropriate retrieval theorem derived. The size of the required data base is $O(n^2)$ independently of the number of simultaneously varying parameters, where $n$ is the total number of component output terminals, and the cost of retrieval is $O(p^3)$ multiplications where $p$ is the actual number of circuit parameters which vary simultaneously in a given analysis. As such, both storage and computational requirements are minimized.
ABSTRACT

DIAGNOSABILITY OF NONLINEAR CIRCUITS AND SYSTEMS - PART II: DYNAMICAL SYSTEMS

RICHARD SAEKS, ALBERTO SANGIOVANNI-VINCENTELLI
AND V. VISVANATHAN
DIAGNOSABILITY OF NONLINEAR CIRCUITS AND SYSTEMS - PART II: DYNAMICAL SYSTEMS

Richard Saeks, Alberto Sangiovanni-Vincentelli, and V. Visvanathan

Abstract

A theory for the diagnosability of nonlinear dynamical systems, similar to the one in Part I for memoryless systems, is developed. It is based on an input-output model of the system in a Hilbert space setting. A necessary and sufficient condition for the local diagnosability of the system, which is a rank test on a matrix, is derived. It is shown that, for locally diagnosable systems, there exist a finite number of test inputs that are sufficient to diagnose the system. Illustrative examples are presented.
ABSTRACT

ANALOG FAULT DIAGNOSIS WITH FAILURE BOUNDS

CHWAN-CHIA WU, KAZUO NAKAJIMA, CHIN-LONG WEY, 
AND RICHARD SAEKS
Analog Fault Diagnosis with Failure Bounds

Abstract

A simulation-after-test algorithm for the analog fault diagnosis problem is proposed in which a bound on the maximum number of simultaneous failures is used to minimize the number of test points required. The resultant algorithm is applicable to both linear and nonlinear systems with multiple hard or soft faults and can be used to isolate failures up to an arbitrarily specified "replaceable chip or subsystem."
1. Title of Investigation: Multidimensional System Theory

2. Senior Investigator: J. Murray

3. JSEP Funds: $27,225.

4. Other Funds:

5. Total Number of Professionals: PI 1 (3 mo.) RA 1

6. Summary:

Our work in multidimensional digital filter design was brought to a conclusion with the publication of a paper describing the design method and giving several examples. Software was also written, tested, and documented to make the VAX/Comtal image processing system function as a digital signal processing and display system; this work was reported in a master's thesis. Work was then begun in two other directions: firstly, in collaboration with Prof. Walkup, robust signal processing algorithms for the restoration of images in the presence of signal-dependent noise were investigated; the results of these investigations will be contained in a doctoral dissertation which was in preparation at the end of the reporting period. Secondly, investigation was begun into the signal-processing aspects of multidimensional inverse problems; as a preliminary to this, a comparative study of the methods used in a typical applied inverse problem was undertaken, the results of which will be reported in a forthcoming master's thesis.

7. Publications and Activities:

A. Refereed Journal Articles

69


B. Conference Papers and Abstracts


C. Preprints


D. Theses and Dissertations:


E. Conferences and Symposia:


ABSTRACT

FEEDBACK SYSTEM DESIGN:

THE SINGLE-VARIATE CASE - PART I

R. Saeks, J. Murray, O. Chua,
C. Karmokolias and A. Iyer
Feedback System Design:
The Single-Variate Case - Part I

by

R. Saeks, J. Murray, O. Chua,
C. Karmokolias and A. Iyer

Abstract

A recently developed algebraic approach to the feedback system design problem is reviewed via the derivation of the theory in the single-variate case. This allows the simple algebraic nature of the theory to be brought to the fore while simultaneously minimizing the complexities of the presentation. Rather than simply giving a single solution to the prescribed design problem we endeavor to give a complete parameterization of the set of compensators which meet specifications. Although this might at first seem to complicate our theory it, in fact, opens the way for a sequential approach to the design problem in which one parameterizes the subset of those compensators which meet the second specification... etc.

Specific problems investigated include feedback system stabilization, the tracking and disturbance rejection problem, robust design, transfer function design, pole placement, simultaneous stabilization, and stable stabilization.
ABSTRACT

SIMULTANEOUS DESIGN OF CONTROL SYSTEMS

R. SAEKS AND J. MURRAY
SIMULTANEOUS DESIGN OF CONTROL SYSTEMS

by

R. Saeks and J. Murray

Abstract

The problem of designing a feedback controller which stabilizes a number of plants simultaneously is discussed from the fractional representation point of view. An abstract solution of this general simultaneous stabilization problem is presented, and an elementary, explicit criterion is given for the simultaneous stabilizability of two systems. Finally, some examples and counter examples are presented, and some open problems are discussed.
ABSTRACT

A DESIGN METHOD FOR TWO-DIMENSIONAL
RECURSIVE DIGITAL FILTERS

JOHN J. MURRAY
A DESIGN METHOD FOR TWO-DIMENSIONAL
RECURSIVE DIGITAL FILTERS

John J. Murray

Abstract

A method for designing two-dimensional, symmetric half-plane recursive
digital filters is presented: a filter is first designed as a parametrized
family of one-dimensional filters; a simple approximation is then used to find
a rational, stable, two-dimensional filter. Some advantages and disadvantages
of the method are discussed, and several examples are given.
ABSTRACT

FRACTIONAL REPRESENTATION, ALGEBRAIC GEOMETRY, AND
THE SIMULTANEOUS STABILIZATION PROBLEM

RICHARD SAEKS AND JOHN MURRAY
FRACTIONAL REPRESENTATION, ALGEBRAIC GEOMETRY, AND
THE SIMULTANEOUS STABILIZATION PROBLEM

Richard Sãeks and John Murray

Abstract

An explicit relationship between the fractional representation approach for feedback system design and the algebro-geometric approach to system theory is formulated and used to derive a global solution to the feedback system problem. These techniques are then applied to the simultaneous stabilization problem, yielding a natural geometric criterion for a set of plants to be simultaneously stabilized by a single compensator.
1. **Title of Investigation:** Detection and Estimation in Imagery

2. **Senior Investigator:** J.F. Walkup  
   T.F. Krile  
   J. J. Murray  
   Telephone: (806)742-3500  
   742-3422  
   742-3506

3. **JSEP Funds:** $27,225

4. **Other Funds:**

5. **Total Number of Professionals:** PI 3  
   RA 2

6. **Summary:**

   This project represents a major effort toward bringing together the techniques of modern estimation and detection theory and real world problems in image processing. Given the fact that the dominant image noise sources such as film grain noise and photoelectronic shot noise are signal-dependent and hence spatially non-stationary, both spatially adaptive and robust estimation techniques are quite attractive. Recently we have investigated both spatially adaptive local estimation techniques as well as techniques designed to be robust with respect to deviations from the assumed signal and noise statistics. We have also discovered techniques for recovering the signal information in an image only from the signal-dependent image noise. A final area investigated is the simplification of the noise filtering problem by first deriving a transformation which converts the signal-dependent noise to signal-independent noise, followed by more conventional linear filtering algorithms.
7. Publications and Activities:

A. Refereed Journal Articles


B. Conference Papers and Abstracts


C. Dissertations:


D. Conference and Symposia:


E. Lectures

1. J.F. Walkup presented a lecture on "Detection and Estimation in Optics," while Visiting Scholar at the Optical Sciences Center, University of Arizona, Tucson, AZ, June, 1982.

ABSTRACT

SIGNAL RECOVERY FROM SIGNAL DEPENDENT NOISE

Rangachar Kasturi, Thomas F. Krile, John F. Walkup
SIGNAL RECOVERY FROM SIGNAL DEPENDENT NOISE
Rangachar Kasturi, Thomas F. Krile, John F. Walkup
Department of Electrical Engineering
Texas Tech University
Lubbock, Texas 79409

Abstract

It is well known that the noise processes corrupting an image are in general signal-dependent. An interesting aspect of signal-dependent noise is that there is a certain amount of signal-information embedded in the noise. Most of the image restoration techniques, however, attempt to suppress the noise terms to obtain an estimate of the image and do not exploit the additional signal information contained in the noise. A simple technique designed to demonstrate the potential for signal extraction from signal-dependent noise is presented in this paper.
Texas Tech University Institute for Electronics Science
Joint Services Electronics Program Research Unit: 6

1. Title of Investigation: Pointing and Tracking

2. Senior Investigator: Thomas G. Newman Telephone: (806) 742-2571

3. JSEP Funds: $27,225

4. Other Funds:

5. Total Number of Professionals: PI 1(1/2 mo.) RA 5 (3 mo.)

6. Summary:

This project is concerned with tracking objects in time-varying images, with respect to a wide variety of motion types, including shifts, magnifications and rotations as well as linear and non-linear deformations produced as the result of projection of a three dimensional scene onto a two dimensional image plane. The research has been mainly concerned with real-time calculation of the motion parameters. Efforts to date have been fairly successful, particularly with regard to a simplified model in which the number of motion parameters is restricted to the four parameters of translation, magnification and rotation. In this case we are able at this time to track an object using real data in the form of digitized TV images. Calculation rates are on the order of 10 iterations (i.e., frames) per second on the VAX 11/780.

With regard to the full set of eight motions possible under the group of projective transformations, the situation is somewhat different. We are now able to track this motion on simulated (i.e., noise-free) data, although an implementation on real data has not been achieved. The execution time depends quadratically on the number of motion parameters, so that doubling the number of parameters has increased the computation
time four-fold. Of more concern, however, is the observation that sensitivity to noise appears to increase with the number of parameters, so that more complex numerical methods are required, resulting in a further increase in the computational load.

In view of the problems with noise in the data, we have begun a study of quality assurance of images for the required type of calculations. This project is proceeding quite well, and should be complete in the coming year. The basic idea is to define an analytical model for the data in a local region of a scene, and use the observed values to determine coefficients in the model so as to achieve a best fit. The next step is to use the correlation coefficient between the model and the data as a measure of image quality. We are able to show that the resulting statistic is indeed a valid indicator of suitability of data for purpose of motion parameter estimation. An unexpected side effect has been observed, which as yet we have not been able to verify theoretically. Namely, the correlation output demonstrates the ability to detect the vanishing of the gradient in a scene, thereby detecting extrema and "roof edges" in the scene.

In summary, the correlation approach has been very successful in explaining certain difficulties in computations attempted on real images.

Progress has also been made in the area of calculation of shape from dynamic imagery. Assuming that motion in the image plane is due to rigid motion in space, describable by six parameters, we find that shape information as well as motion information is encoded in the observed image, whose motion is modelled by the eight parameter group of projective transformations. We have recently been successful in calculating the slopes of a plane in space from data observed in the motion sequence of
a time-varying image of the plane. Of course, there can be relative motion between the image plane and the observed object. We do not assume that the trajectory is known.

7. Publications and Activities:

A. Refereed Journal Articles


B. Dissertations: Theses, Reports

1. Terral, Donna, "A Velocity Field of Differential Forms," Masters in Mathematics, Texas Tech University,

C. Conferences and Symposia

1. DECUS Spring 82, Digital Equipment Corporation, Atlanta, Georgia, Spring 1982.
ABSTRACT

THE GEOMETRY OF SECOND ORDER LINEAR
PARTIAL DIFFERENTIAL EQUATIONS

GREGORY A. FREDRICKS
The Geometry of Second Order Linear Partial Differential Equations

by

Gregory A Fredericks

Abstract:

The micro-local results concerning the theory of canonical forms for second order linear partial differential equations is well-known and is developed in most advanced textbooks on the subject. This theory gives necessary and sufficient conditions for reduction of the top order part of the equation to constant coefficients.

This paper formulates two macro-local problems on the reduction of the top order part of a linear partial differential equation to constant coefficients. General results on the solution of these problems is presented along with some results on the consequences of the theorem of Cotton.
GRANTS AND CONTRACTS ADMINISTERED BY JSEP PERSONNEL

A. Funded

Hunt, L.R., NASA, "Nonlinear Systems," 1 year, 10/1/82-9/30/83, $31,325.


Saeks, R., State of Texas Matching "Joint Services Electronics Program" $30,000, ends May 31, 1983.


Walkup, J.F., SPIE, Optical Engineering Education" $7,000, open.
GRANTS AND CONTRACTS IN ELECTRICAL ENGINEERING

A. Systems


Saeks, R., State of Texas Matching "Joint Services Electronics Program" $30,000, ends May 31, 1983.


Gustafson, D., E. Systems "Digital and Optical Signal Processing", $17,991, open

Emre, E., AFOSR, "On a Theory of Control for Linear Multivariable Systems Over Rings" $33,404, ends June 1983.


Chao, K.-S., NSF "Continuation Methods in Nonlinear Networks" $44,751, ends December 31, 1983.


Nakajima, K., Institute for University Research in Engineering, "Adaptive Systems Diagnosis" $6,000, ends August 1983.

Hardwick, M., College of Engineering Initiation Grant, "Applicative Languages in Database for Computer Aided Design Applications", $1,000, ends August 31, 1983.


Walkup, J.F., SPIE, Optical Engineering Education" $7,000, open.

TOTAL ANNUAL SYSTEMS FUNDING $543,634
B. Electro Physics


Hagler, M.O. and Kristiansen, M., State of Texas Matching "Investigation of RF Plasma Heating in Toroidal Geometry" $27,000, ends August 31, 1983.


Portnoy, W.M., ONR "Reliability Study of Refactory Gate Gallium Arsenide MESFETS" $50,000, ends December 1982.

Portnoy, W.M., AFWL "Investigation of the Physics of Failure in Semiconductor Resulting from Electrical Transients", $60,000, ends September 30, 1983.

Williams, P.F., Research Corp., "Driven Raman Processes as Sources of Coherent Excitation" $3,815, open.

Kristiansen, M., "Basic Problems in High Power RF Heating and Confinement in Magnetoplasma" $1,421, open.

TOTAL ANNUAL ELECTRO PHYSICS FUNDING $287,892.

Pulsed Power Research


Kunhardt, E., NSWC "Breakdown in High Voltage", $47,000 ends June 30, 1983.

TOTAL ANNUAL PULSED POWER RESEARCH FUNDING $930,630

POWER SYSTEMS

Reichert, J.D. DOE, "Crosbyton Solar Project", 0 - $4,000,000, from 0 - 3 years.

Craig, J.P., DOE, "Power Systems Studies" $8,000, ends December 31, 1982

*TOTAL ANNUAL POWER SYSTEMS FUNDING $8,000

*Crosbyton Solar Project excluded pending completion of negotiations.
OTHER

Seacat, R.H., "Research and Development", $19,000, ends August 31, 1983.

TOTAL OTHER FUNDING $ 19,000

TOTAL ANNUAL FUNDING IN ELECTRICAL ENGINEERING $ 1,789,246
Grants and Contracts in Mathematics


Harris, Gary, NSF, "Geometry and Analysis for Problems in Partial Differential Equations," 2½ years, 7/1/82 - 12/31/84, $18,777.

Hunt, L.R., NASA, "Nonlinear Systems," 1 year, 10/1/82-9/30/83, $31,325.


Nelson, Paul, matching funds from TTU, "Computational and Mathematical Aspects of Radiation Transport," 2½ years, 11/1/80 - 4/30/83, $10,000.


Victory, H.D. "The Study of Wave Propagation through Inhomogeneous Media," Arts and Sciences Research Award, 1 year, 9/1/82 - 8/31/83. $6,000.

Victory, H.D., Humboldt Fellowship in Germany, Alexander von Humboldt Foundation, 1 year, 9/1/82 - 8/31/83, 28,000 Deutsch Marks.

TOTAL ANNUAL FUNDING IN MATHEMATICS $242,698
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
Publications by JSEP Personnel

A. Refereed Journal Articles


B. Conference Papers and Abstracts


C. Preprints


D. Theses and Dissertations:


E. Conferences and Symposia


Hunt, L.R., SIAM 30th Anniversary Meeting, Stanford University, July 1982.

Hunt, L.R., CNRS Conference, Belle Ile, France, Sept. 1982.


Murray, J., Texas-Oklahoma SIAM Section Annual Meeting, Oklahoma City, April 1982.


F. Lectures

Walkup, J.F., presented a lecture on "Detection and Estimation in Optics," while Visiting Scholar at the Optical Sciences Center, University of Arizona, Tucson, AZ, June 1982.

Walkup, J.F., presented a lecture on the research results at the U.S. Army Night Vision Laboratory in September 1982.
END

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