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CASE SCHOOL OF ENGINEERING

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RESEARCH AREAS AND APPLICATIONS

- **Hybrid Systems: those mixing continuous-time processes and digital logic**
- **Real-Time Control over Computer Networks**
- **Engineering Hybrid Systems: Robotic Assembly, Task and Motion Planning, Flexible Manufacturing, Flight Control, etc.**
- **Learning in animals, modeling heart biolectricity**

APPROACH

- **Mathematical analysis of "hybrid systems" (those mixing continuous-time processes and digital logic**
- **Computer modeling and optimization of such systems**

COLLABORATIONS (current and former)

- **NASA, Wright-Patterson AFB**
- **Ford Motor Co. Advanced Technology Division**
- **OhioICE (including Rockwell, Keithley, ABB, Eaton)**
- **Siemens Corporate Research Center (Munich)**
- **MIT, U. Illinois at Urbana-Champaign, Lund Inst. Tech.**

RESEARCH SPONSORS

- **NSF, NASA**
- **Automotive, Manufacturing Firms**

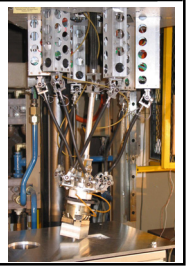
RECENT ACCOMPLISHMENTS

- **Developed a new means of programming robots to exploit the sense of touch during mechanical assembly**
- **Computed maximum delays preserving stability in a networked control system**
- **Invented an algorithm for optimal control of hybrid systems**
- **Predicted flexible parts feeder throughput via GSMP models**
- **Automated manufacturing assemblies previously only accomplished by humans [as part of a CWRU team]**
- **Patented a control algorithm for continuous-casting steel mills**
- **Proved the stability of a flight control law previously only validated by simulation**

Intelligent Assembly for Automotive Applications

In the picture to the right is the ParaDex-1 (built by Micro-Dexterity Systems in collaboration with Sandia National Labs). This robot "lives" in the Glennan Bldg at CWRU and is controlled using algorithms developed by my collaborators, my students, and I.

We received Best Video Award for this work at 2002 Intl. Conf. Of Robotics and Automation. (See website for movie.)



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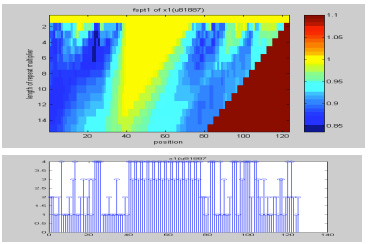
RESEARCH AREAS AND APPLICATIONS

- **Joint time-frequency signal analysis**
- **Wavelet Theory and applications**
- **Multi-resolution signal decomposition**
- **Analysis of Periodic Components in DNA sequences**
- **Tornado detection using 2-D wavelets on radar images**

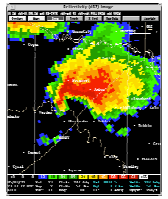
Analysis of Periodic Components of DNA sequences

- **Short-time Periodicity Transform**
- **Provides robust properties and information visualization**



RECENT ACCOMPLISHMENTS

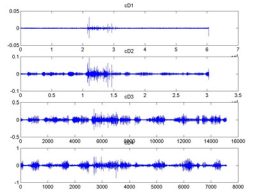
- **Wavelet Filtering of noise corrupted audio signals**
- **Analysis of doppler radar images using wavelets**



Discrete Wavelet Transform of Noisy Audio Signal

Sample Audio Signal

Denoised Signal



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Research Areas and Applications:

- **Robotics**
  - –Medical Robotics, Haptics, and Teleoperation
- **Computer Graphics / Virtual Environments**
  - –Surgical Simulation, Physical Modeling
- **Systems and Control Theory**
  - –Modeling and Simulation of Biological Systems

APPROACH

- Develop Intelligent Robotic Tools for Off-Pump (Beating Heart) Coronary Artery Bypass Graft Surgery
- Study Real-Time Finite Element Models of Deformable Objects for Surgical Training Simulators
- Develop an Open Source / Open Architecture Software Framework for Surgical Simulation
- Study Hierarchical Models for Organ Level Simulation in the Digital Human

COLLABORATIONS

- Carnegie Mellon University
- University of California, Berkeley
- University of California, San Francisco
- University of Michigan, Ann Arbor

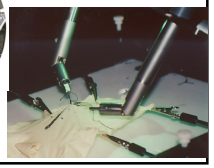
RESEARCH SPONSORS

- National Science Foundation
- DARPA

RECENT ACCOMPLISHMENTS

- Proposed a novel Active Relative Motion Canceling algorithm for tracking heart motion
- Developed a task-based optimization framework for design of bilateral teleoperation controllers
- Proposed a new fidelity measure for telesurgical system design
- Developed and analyzed a novel multi-rate simulation scheme for haptic interaction with deformable objects in virtual environments

UCB/UCSF Robotic Telesurgical Workstation for Laparoscopy



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RESEARCH AREAS AND APPLICATIONS

- **Large Scale Optimization and Multi-objective Optimization**
- **Application of Optimization for Optimal Treatment Planning of Radiation Therapy such as Gamma Knife for Brain tumors and Intensity Modulated Radiation Therapy for Prostate Cancer**
- **Applications of Optimization and System Methodology to Production Planning and Control, Supply Chain Management, Magnetic Resonance Imaging (MRI), Power System Planning, Pattern Recognition, and Data Compression**

APPROACH

- **Specialized Logic-based Decomposition Strategies and Custom Optimization Algorithms for Specific Large Scale Applications**
- **Integrated Production Planning and Control Software Systems with Decision Support (ERP, MRP II) for Custom Applications for Small to Medium Sized Enterprises (SMEs) (Productivity Improvement)**

COLLABORATIONS

- **Q. Jackie Wu, Dept. of Radiation Oncology, School of Medicine, CWRU and University Hospitals**
- **Jingshi Liu, Dept. of Biomedical Engineering, Cleveland Clinic Foundation**
- **J. Duerk, Dept. of Radiology, School of Medicine, CWRU**
- **National Science and Technology Development Agency (NSTDA), THAILAND**

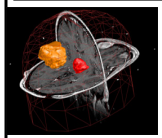
RESEARCH SPONSORS

- **Whittaker Foundation**
- **EPRI, USAID, Fulbright Foundation**
- **NSTDA**

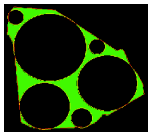
RECENT ACCOMPLISHMENTS

- **Large scale optimization algorithms for designing optimal treatment plans for radiosurgery of brain tumors by Gamma Knife**
- **Logic-based optimization algorithms for optimizing production planning and inventory management in a supply chain**
- **Decomposition algorithm for multi-criteria design of gradient waveforms for MRI**
- **Efficient algorithm for clustering analysis, cell formation for cellular manufacturing and for facility layout**
- **Efficient Algorithm for Operations Assignment for Production of Printed Circuit Boards**
- **Efficient Algorithm for Unit Commitment and Economic Dispatch in Power Industry**
- **Algorithm for Quadratically Constrained Quadratic Programming problems with Applications to Design of Experiments and Response Surface Methodology**

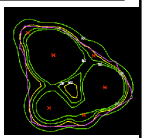
Optimal Treatment Planner for Gamma Knife Surgery of Brian Tumors (with Q. Jackie Wu)



Tumors in the Brain



circles indicating 50% isodose of each shot



isodose plotted: 70% 60% 50% 30%

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RESEARCH AREAS AND APPLICATIONS

MIXED-SIGNAL SENSOR INTERFACING AND COMMUNICATION

- Wireless sensor interfacing for harsh environments, including high-temperature and biological systems
- Medical imaging, specifically low-power/miniature applications
- Electronic intensive approach to fluid sensing for water purity, oil cleanliness, and biochemical detection
- High-voltage actuation for massively parallel arrays of electrostatic actuators

APPROACH

- IC/PCB design, and PCB fabrication in CWRU MSIC Lab
- IC fabrication using DARPA/NSF MOS Implementation System
- MEMS/sensor fabrication by collaborators

COLLABORATIONS

- Movaz Networks, Inc. (Golub)
- NASA Glenn Research Center (Neudeck)
- Cleveland Clinic Foundation (Fleischman) and Queens University (Lockwood)
- Biology (Chiel), Medicine (Drotar), ECHE (Martin) EECS (Mehregany, Zorman, Tabib-Azar, Buchner, Merat)

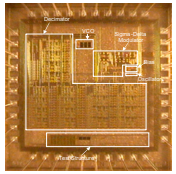
RESEARCH SPONSORS

- Glennan Microsystem Initiative
- PolyDisplay Corporation
- NASA
- Cleveland Clinic Foundation

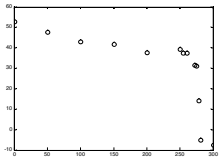
RECENT ACCOMPLISHMENTS

- 1920-channel, 200-Vac, Digital-to-Analog Converter for Optical MEMS
- 250ºC, 8-bit Analog-to-Digital Converter for Wireless Sensors

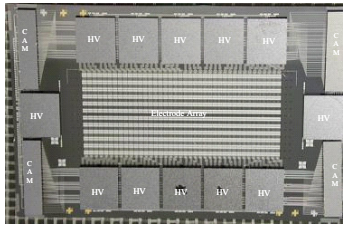
SOI Sensor Interface IC



Measured Performance



High-Voltage Driver Module for MEMS Optical Switch



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RESEARCH AREAS AND APPLICATIONS

- Ultrasonics
- Electrical Networks
- Materials

APPROACH

In a typical experiment, tiny ultrasonic transducers are implanted on both faces of a fatigue specimen along the principle axis. One transducer serves as the transmitter and the other as a receiver. Sharp ultrasonic signals are launched along the specimen monitoring simultaneously its length, diameter and the generation of cracks. Neither strain-gages or extensometers are necessary. Supported by NASA.

COLLABORATIONS

- G.R. HALFORD — Strength of Materials (NASA)
- J.L. Katz — Biomedical Engineering
- G. Welsch — Materials Sciences & Engineering

RESEARCH SPONSORS

- NASA

APPLICATIONS

Monitoring On Site For Life

- Bearing wear (commercialized).
- Strain.
- Surface layers growth, strain and cracks.
- Fatigue testing in aggressive environment.
- Crack detection and characterization.

Monitoring Titanium Implants in Bones

- Bone penetration, resorption and regrowth in titanium cavities.

SELECTED RECENT JOURNAL PUBLICATIONS

- Hazony, D. (1999) Stress wave propagation when the elastic coefficients vary with depth. *Circuits Systems Signal Processing.* 18, No, 2, pp. 27-42.
- Hazony, D. (1997) Time limited and Band limited environment – signals and systems. *Circuits Systems Signal Processing,* 16, No. 2, pp.1-24.
- Hazony, D. (1995). Impulse stress wave propagation in elongated bodies, *Circuits Systems Signal Processing,* 14, No. 4, pp.525-238.
- Hazony, D. (1991). Edgeless short-pulse piezoelectric transducers, J. Acoust. Soc. Am. 86 (4), pp. 1230-1233.

PATENTS

A sequence of 8 patents has been evolved for on-site monitoring of wear members (such as bearings, seals, valves and clutches). The transducer is an integral part of the wear member.

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Research Areas and Applications:

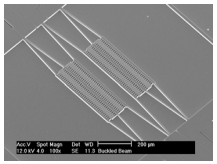
- Solid State Electronic Devices and Technology
- Micro Sensing Systems in Harsh Environments
- Environment Powered microwatts telemetry systems
- Micro-Electro-Mechanical Systems—Physical Sensors, Actuators
- Implant Electronics & Instruments for Bio-Medical Applications
- Packaging of Micro Devices and Systems for Bio-Med. Applications

Buckled Beam Linear Output Capacitive Strain Sensor

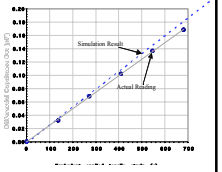
Features:

- High sensitivity by using a mechanical amplification scheme of a buckled beam
- Comb drive differential capacitive output

A strain sensor device



Measured Characteristics



Recent Accomplishments

- Touch Mode Capacitive Pressure Sensor—DARPA Grant, 3 Patents
- High Performance Strain Sensor & Telemetry Systems—ARO Contract
- Chronic Monitoring Of In Vivo Blood Pressure–A Part Of NSF Grant
- Micro Sensor For Implantable Cochlear Hearing System—NIH Grant
- RF Transmission in Body for In Vivo Sensor Networks---NASA Grant
- Editorial Board of Sensors And Actuators-A and MicroSystem Technologies
- Chairman, Executive Committee of Asian Pacific Transducers and MEMS/NEMS Conference Series, 2002-2004
- Chairman, Transducer Research Foundation That Sponsors the Hilton Head S. & A. Workshops and MEMS Related Conferences Worldwide, 1996-present

INITIATING RESEARCH PROJECTS

- Carbon Nano Spheres for Sensors and Electronic Devices
- Environmentally Powered In Vivo Sensors and Sensor Network
- High Temperature (600 ºC) Sensor Array and Telemetry systems
- Rapid Bonding and Mechanical Gain in Strain Sensors Packaging

AWARDS AND OTHERS

- Career Achievement Award, Transducer 97, 1997
- Outstanding Research Award, 4th Int. Meeting on Chem. Sensors
- IEEE Fellow (76) and Am. Inst. of Med. & Bio. Eng. Fellow (92)
- Professor of PEN-TUNG SAH Research Center, Xiamen University, Xiamen, China

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RESEARCH AREAS AND APPLICATIONS

- Nonlinear Control and Dynamic Systems
- Adaptive and Robust Control
- Nonholonomic Mechanical Systems and Robotics
- Fault Detection and Diagnosis
- Control of Biologically Inspired Systems

APPROACH

- Passivity Based Low-Gain Feedback Technique
- Adding a Power Integrator
- Homogeneous Observer and Non-Separation Principle Based Design
- Discontinuous and Time-Varying Control
- Output Feedback

RESEARCH SPONSORS

- NSF (DMS, ECS, GOALI)
- Rockwell Automation
- Orbital Research Inc.

RECENT ACCOMPLISHMENTS

- JSPS Fellow (Japan Society for Promotion of Science)
- Developed General Nonsmooth Feedback Methods for Global Control of Inherently Nonlinear Systems
- Developed a Powerful Tool known as Adding a Power Integrator and a systematic output feedback method for Nonlinear Systems with Uncontrollable/Unobservable Linearization
- Applications in Robotics, Nonholonomic and Underactuated Mechanical Systems, and Biologically Inspired Systems

COLLABORATIONS

- Orbital Research Inc.
- Washington University
- Univ. of Manchester Institute of Science & Tech., U.K.
- Sophia University, Tokyo, Japan
- Tokyo Denki University
- Universita di Roma "La Sapienza", Italy
- Nanyang Technology University, Singapore
- Chinese Academy of Science, Beijing, China

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RESEARCH AREAS AND APPLICATIONS
- Nonlinear and stochastic control theory and applications
- Fault detection, diagnosis and prognosis
- Integrated control and diagnostics of electrical machines
- Advanced Signal Processing for:
  - fault detection and isolation
  - epilepsy monitoring and prediction
  - analysis of physiological signals
  - monitoring, state classification and anomaly detection

APPROACHES
- Hidden-Markov Modeling
- Model-Based Nonlinear Filtering for real-time fault detection and diagnosis
- Tracking of nonlinear (chaotic) behavior using advanced signal process and time series analysis techniques
- Passivity-based nonlinear control methods

COLLABORATORS
- Mechanical and Aerospace Engineering
- Electronics Design Center
- Rockwell International
- CWRU School of Medicine and Cleveland Clinic Foundation

RESEARCH SPONSORS
- NASA
- Boeing/Rockwell
- NIH
- NSF

RECENT ACCOMPLISHMENTS:
- Developed new algorithms for lube health monitoring and prognostics from multi-element sensor array data
- Developed algorithms for speed and defect frequency estimation for ball bearings using vibration data
- Developed a real-time diagnostic and prognostic system for rolling element bearings
- Developed advanced algorithms for the detection and diagnosis of mechanical and electrical faults in induction machines
- Developed advanced nonlinear control algorithms for induction motors operating under unknown load, variable rotor resistance and magnetic saturation
- Developed a real-time epileptic seizure detection and prediction algorithm

RECENT ACCOMPLISHMENTS:
•Developed a real-time model-based system for the detection and diagnosis of faults in rotating machinery

Motor and Gearbox Vibration Test Rig
- •Rotor Faults
- •Stator Winding Faults
- •Motor Bearing Faults
- •Gear Bearing Faults
- •Gear Faults

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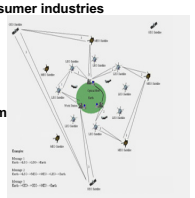
RESEARCH AREAS AND APPLICATIONS
- Trait & Mathematical Modeling of Biological Systems
- Intelligent Mobile Agents & Tele-communications Networks
- Multi-objective Manufacturing/Production/Operations Optimization
- Artificial Neural Networks and Clustering
- Design, Layout, Facilities, & Group Technology
- Decision Making Typology, Analysis, & Optimization

INTELLIGENT TELE-COMMUNICATION NETWORKS
Motivation
- •Develop intelligent design and optimization of tele-com networks and routers
- •Generate reconfigurable networks, routers, and packets
- •Improve quality and speed for space & terrestrial networks
- •Support the developing consumer industries

Approach
- •Intelligent Mobile Agents
- •Intelligent Packets
- •Intelligent Routers
- •Clustering&Swarm Algorithm
- •Assimilation and Simulation



Collaboration
- •NASA Glenn

RECENT SPONSORS AND COLLABORATION
- •NASA – Tele-communications Division: Intelligent Networks
- •GE – Lighting Division: Layout-Group Technology, Clustering of HID bulbs facilities
- •Parker Hannifin: Machinability, Tool Life, Machine Set-up, and Off- & On-line Supervision
- •B. F. Goodrich: Design & Production of New Polymers; Optimal Parameter Selection
- •NSF: Mathematical Foundation for Machine Learning

DESIGN & ANALYSIS OF MANUFACTURING SYSTEMS
Motivation
To develop a systematic approach for design, analysis, and optimization of operational systems by considering conflicting multiple criteria in decision making

Approach
- •Interactive multi-objective optimization & decision making
- •Discovering problem domain and learning optimal decision making behavior

Application areas:
- •Uni- and Bi- direction Network Layouts
- •Facility Layout/Re-layout
- •Scheduling and Sequencing
- •Resource Allocation and Aggregate Planning
- •Assembly Line Systems and Balancing

CASE WESTERN RESERVE UNIVERSITY
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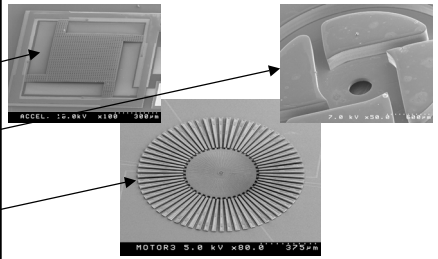
Research Areas and Applications
- Microelectromechanical Systems (MEMS)
- Silicon Carbide Material and Process Technology
- Micromachining and Microfabrication Technologies

Approach
- Design/Modeling of New Sensors and Actuators
- Silicon Carbide for High Temperature Devices
- Fabrication/Process Technology Development

Collaborations
- Glennan Microsystems Initiative (http://www.glennan.org/)
- Ohio MEMSNet (http://mems.cwru.edu/memsnet)
- Aerospace MEMS Consortium (BFGoodrich and Parker Hannifin)
- NC State University (Prof. R. Davis on GaN)

Research Sponsors
- ARO, DARPA, NASA, NSF, CAMP

Recent Accomplishments
- Development of a Multi-Project Silicon Carbide (SiC) Surface Micromachining Process with Device Design Complexity Capabilities Paralleling the State-of-the-art in Silicon
- Development of Bulk Micromachining Techniques for SiC, Demonstrated by Fabrication of SiC Atomizers for Industrial and Medical Applications
- Development of a Nickel Wire Bonding Technology for High Temperature Operation of SiC Devices
- Development of Silicon Micromotors for Optical Scanning and Switching Applications



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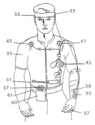
RESEARCH AREAS AND APPLICATIONS
- Wireless systems (rfid and rf circuit design, sensor webs)
- Sensors (MEMS-based and optical)
- Image Processing
- Ad hoc wireless computer networks
- Engineering applications of neural networks and pattern recognition

APPROACHES
- MultiPoly™ fabrication of controlled optical shapes
- Using human body as RF communications channel

COLLABORATIONS
- Rockwell Autmation
- NASA Glenn Research Center

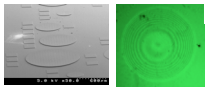


RESEARCH SPONSORS
- Rockwell Automation
- NASA

Rockwell Automation

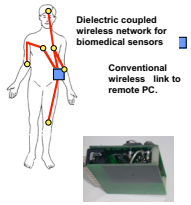
Space Communications in CICT

RECENT ACCOMPLISHMENTS
- Produced MEMS reflectors suitable for optical communications applications, .



OPTICAL TESTING OF 1mm DIA, 7mm focal length CONCAVE REFLECTORS FABRICATED USING MultiPoly™ PROCESS

Wireless Biosensor Network



The goal of this work is to develop a wireless, low-loss intrabody communications system for biomedical sensors. Such a wireless system will have great advantages over the wired vest type systems currently used by astronauts and firemen.

CASE WESTERN RESERVE UNIVERSITY
CASE SCHOOL OF ENGINEERING

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RESEARCH AREAS AND APPLICATIONS

- Systems Biology
- Global Change and Sustainable Human Development
- Mathematical Theory of General Systems
- Complexity and Multi-level, Hierarchical Systems

COLLABORATIONS

- European Commission: Sustainable Development and Information Age
- St. Petersburg Technical University, Russia
- Chiba Institute of Technology, Japan
- University of Catalunya, Barcelona, Spain
- Systems Biology Network

RECENT ACCOMPLISHMENTS

- UNESCO Scientific Advisor on Global Change
- Co-Director, Global-problematique Education Network Initiative (GENIe)
- Co-Director, GENIe European Office, Polytechnic University of Catalonia, Terrassa, Barcelona, Spain
- Global Issues and Sustainable Human Development Undergraduate Textbook
- Co-Author of two books
- Presenter of the Keynote Address at the Systems Biology Conference held in Santorini, Greece.
- Systems Biology Progress Report #4

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RESEARCH AREAS AND APPLICATIONS

Mechatronics: design and control of intelligent electromechanical and robotic systems

- **applications to:**
  - agile manufacturing and mechanical assembly
  - Network-based supervisory control of remote intelligent systems
  - reflexive, adaptive and learning systems
  - biomedical applications in orthotics, prosthetics and radiation oncology

APPROACH

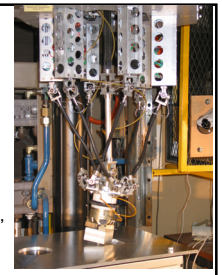
- Collaborative, interdisciplinary design projects invoking skills in system modeling, analysis, and synthesis of creative solutions, typically exploiting real-time computer controls
- Depth of experience in force feedback for robotic assembly
- Biological inspiration for reflex and learning control

COLLABORATIONS

- Ford Motor Co., Dynamotors, Inc., ABB Robotics, MicroDexterity Systems, Inc., Geauga Rehabilitation Engineering

RESEARCH SPONSORS

- NSF, NASA, NIH

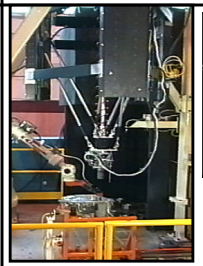


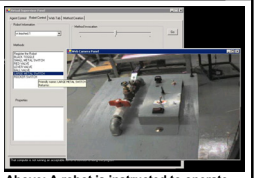
ParDex-I robot at CWRU inserts a square block into a square hole using feeling and intelligent control.

RECENT ACCOMPLISHMENTS

Right: ParaDex-II assembles an automotive transmission using feeling in a demonstration workcell in Detroit

Above: EOG signals from eye movements are used to control a robot arm. This research applies to rehabilitation robots and to designing neural prosthetic controllers.





Above: A robot is instructed to operate mechanical devices that require a sense of feeling. Network-based remote control uses a webcam, a GUI and supervisory commands to perform remote operations.

CASE WESTERN RESERVE UNIVERSITY
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RESEARCH AREAS AND APPLICATIONS

- Embedded Systems Design, Software & Hardware
- Design Automation of Electronic Systems
- Reconfigurable Computing
- VLSI / CAD and Testing
- Computer Architecture and Parallel Processing

COLLABORATIONS

- Conexant, Rockwell, Synopsys, Intel, Cisco

RESEARCH SPONSORS

- NSF, NASA, Conexant, SRC

SELECTED JOURNAL PUBLICATIONS

C. Parachristou, M. Norani, S. Spining, Multiple Clock Scheme for Low Power RTL Design, *IEEE Trans. On VLSI*, June 1999.
C. Parachristou, M. Baklashov, K. Lai, High Level Test Synthesis for Behavorial and Structural Designs, *J. Electronic Testing*, October 1998.
C. Parachristou and M. Immaneni, Vertical Migration of Software Functions and Algorithms with Enhanced Microsequencing, *IEEE Trans. On Computers*, January 1993.
C. Parachristou abd H.S. Lim, A Large Grain Mapping Method for Parallel Scientific Computers, in *Parallel Computational Fluid Dynamics*, MIT Press, October 1992.
C. Parachristou and N. Sehgal, An Improved Method for Detecting Functional Faults in Semiconductor Memories, *IEEE Trans. On Computers*, March 1985. (Widely quoted in over 400 publications, implemented in industry.)

RESEARCH PROJECTS

Design and Test Strategies for Embedded Systems on Chip (SOC).

Goal: Develop methods, techniques and tools for design & testing of complex SOCs. Funded by NSF and industry.

Reconfigurable Communications Processor:

Goal: Design, simulation and prototyping of an advanced reconfigurable communications processor for space applications. Funded by NASA, NSF.

Test Compression for Embedded Cores using LZW.

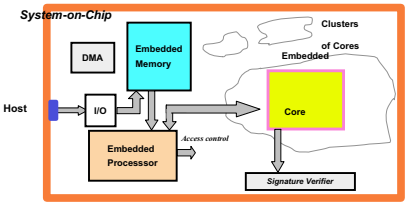
Goal: Develop a compressor and hardware on-chip decompressor achieving high test pattern compress ratio using a novel application of the LZW algorithm. Important in other on-board embedded applications to communications and networking.

Soft Error Detection in Embedded Memory Cores

Goal: Develop an enhanced memory cell sensor design that monitors error bit flippings due to radiation and other transients.

Design and Test Strategies for Embedded System-on-Chip

Goal: develop methods , techniques and tools for design and testing complex System-on-Chip. Funded by NSF and industry



CASE WESTERN RESERVE UNIVERSITY
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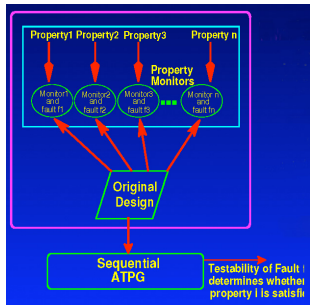
RESEARCH AREAS AND APPLICATIONS

- Verification and test of switch-level circuits
- Gate-level extraction for transistor-level design
- Automatic test pattern generation(ATPG) for VLSI circuits
- Reconfigurable Computer-Aided Design



BMC ATPG Approach

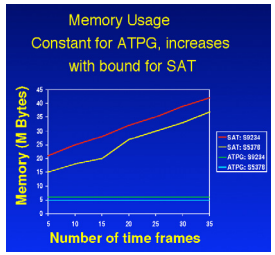
- An LTL property is mapped into a line fault
  - No modification to original design
- The property holds when the fault is untestable

FORMAL VERIFICATION USING ATPG BOUNDED MODEL CHECKING

- A crucial step in the design process
  - –Full verification required to insure correct operation
  - –60% of the design effort is spent on verification (expected to increase to 80%)
  - –Discovering deeply buried bugs using simulation is less likely as design grows larger - confidence in the design grows larger
- Growing interest in formal verification as a technique to handle difficult cases

FORMAL VERIFICATION TECHNIQUES

- Used to establish equivalences between RTL and logic-level
- Industry is showing a great deal of interest to verify formally the correctness of RT-level designs
- The main approach to verifying a design is to show that it satisfies PROPERTIES stated in a formal fashing expressed in Linear Time Temporal (LTL).
  - –Safety: Expresses the fact that something bad will never happen
  - –Liveness: Express the behavior whereby something good will eventually happen
  - –Fairness: Expresses the fact that expected behavior should be repeatable



RESULTS

- In contrast to current beliefs, we showed that ATPG search is superior to traditional SAT based search
- We showed that use of ATPG-based search will allow formal verification on much larger designs than with SAT-based search

CASE WESTERN RESERVE UNIVERSITY
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RESEARCH AREAS AND APPLICATIONS

- Systems Biology
- Systems Approach to Global Change
  - Visioning/Future Studies
  - Resource Scarcity and Development Problematique (water, carrying capacity, energy, IT labor etc.)
- Complex Systems Analysis and Simulation Architecture
- Informatics Application in Medicine

APPROACH

- Systems Science, Complex Systems, Simulation Architecture
- Merging Objective and Subjective elements
- Informatics

COLLABORATIONS

- United Nations Educational, Scientific and Cultural Organization.
- Whitehead Institute, Duke Medical Center and Univ. Rostock (Germany)
- World Water Commission
- Govts. of Kazak, Kyrgyz, Tajik, Turkmen, and Uzbekistan
- Polytechnic Univ of Catalunya, Barcelona
- University of Wisconsin, Madison, Cleveland Clinic Foundation

RESEARCH SPONSORS

- Packard Foundation
- Nord Foundation
- NSF-IAI and NIH-NIAA
- PRI
- Provost Oppr. Fund.

RECENT ACCOMPLISHMENTS

- Formed a Systems Biology Group at Case
- UN WWAP/PCCP Panel Member
- World Water Commission, Scenario Analysis Panel
- Developed a Computer Based Tool GLOBESIGHT implementation on MS Windows and Java for Strategic and Policy analysis
- Developed Vision Statement on Water for Aral Sea Basin Countries in conjunction with five government representatives (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan)
- Developing a worldwide network of Systems Biology Researchers
- Managing a network of Universities and Developing a new network High Schools under the UNESCO GENIe Program
- Developing a series of Workshops around the globe with UNESCO GENIe European Office.

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Case School of Engineering

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RESEARCH AREAS AND APPLICATIONS

* Solid-Electrolyte Very High Density Memory Devices
* Molecular Electronics
* Quantum Computing
* Nano-metrology tools; Microwave Atomic Scale Metrology
* Novel Micro-Actuators and device phenomena

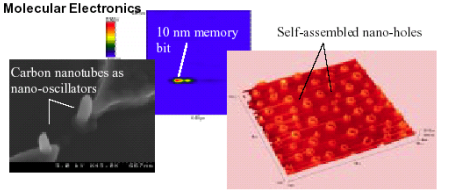
COLLABORATIONS

* International: Hebrew University, University of Chemnitz
* National: Yale, UMKC, Government Labs, NIST, NASA, AMD and Intel
* Local: Chemistry, Chemical Eng., Physics, Biomedical Eng., Chemical Eng., and Macro Depts., NASA, Ferro, and Erico.

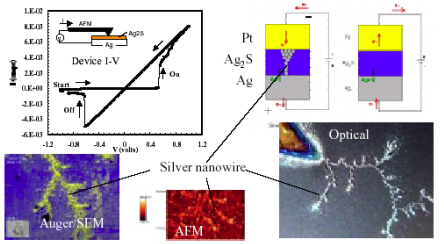
RESEARCH SPONSORS

* Air Force, Boeing, Ohio Board of Regents, NASA, SRC

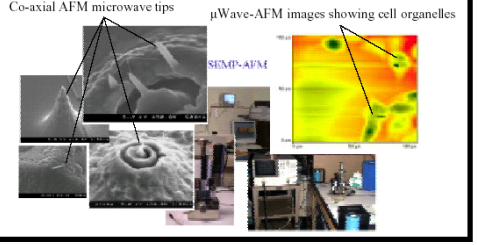
Molecular Electronics



Solid-Electrolyte Very High Density Memory Devices



Nano-metrology tools; Microwave Atomic Scale Metrology



CASE WESTERN RESERVE UNIVERSITY
CASE SCHOOL OF ENGINEERING

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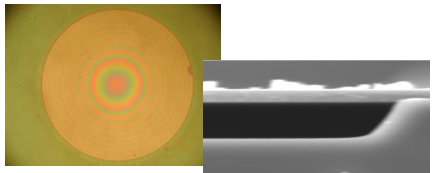
RESEARCH AREAS AND APPLICATIONS

- MEMS Design and Fabrication Technology Development
- RF MEMS for Wireless Communications
- MEMS Sensors for Biomedical and Harsh Environments
- Low-Power, Low-Noise CMOS MEMS Interface Ics
- Low-power Telemetry Circuits Design
- CMOS RF Low Phase Noise VCOs

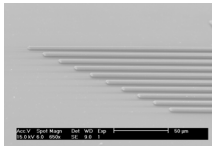
SiC Capacitive Pressure Sensor
SiC Materials -> High Temperature (500˚C) Operation



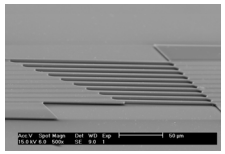
Top View of SiC Pressure Sensor

Sensor Cross-Section SEM

Single Crystal Silicon MEMS Fabrication Technology
H+ Implant & Smart Cut -> Novel Single Crystal Si MEMS



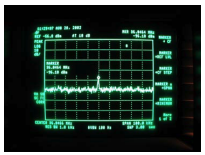
Silicon Cantilever Beams



Clamped-Clamped Si Microbridges

High Temperature MEMS Wireless Sensing and Communications

Wireless MEMS Sensor



Received Sensor Information at 1.5-meter distance (250˚ C)

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RESEARCH AREAS

- Growth, characterization, and applications of silicon carbide thin films
- MEMS and NEMS processing techniques and devices
- Nanopore membranes for drug delivery systems
- Biomedical sensor fabrication techniques
- Surface treatments for micro and nanofabricated devices

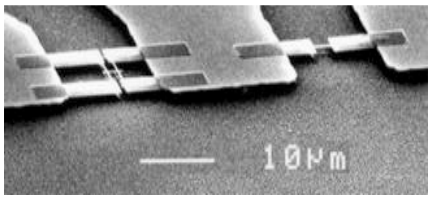
APPROACH

- Development of thin film deposition techniques for high quality single and polycrystalline 3C-SiC on large area substrates by LP-, AP-, PE-, and RTCVD processes
- Development of novel patterning techniques for thin film MEMS and NEMS devices.

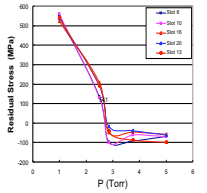
CURRENT OUTSIDE COLLABORATIONS

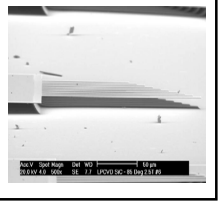
- ***Caltech:*** Nanomechanical SiC high frequency resonators
- ***Northwestern Univ.:*** Mechanical testing of SiC films
- ***U. Erlangen (Germany):*** Surface properties of SiC
- ***Cleveland Clinic Foundation***: Drug delivery microdevices
- ***Iowa State University***: Laser micromachining techniques
- ***U. of Edinburgh (Scotland):*** 3C-SiC resonant structures
- ***Argonne National Lab:*** Microscale electron beam structures

Silicon Carbide for Ultra-High Frequency Applications
- Development of 3C- and 6H-SiC nanomechanical resonators with fundamental resonant frequencies exceeding 1 GHz.



Polycrystalline 3C-SiC for MEMS
- Development of stress and stress gradient control in LPCVD SiC thin films for SiC surface micromachining using a high throughput reactor





CASE WESTERN RESERVE UNIVERSITY
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RESEARCH AREAS AND APPLICATIONS

- Efficient Utilization of Spectrum for Space Telemetry
- Regenerative Ranging Measurements to Spacecraft
- Design of Power-Efficient Telemetry Schemes
- Characterization of Phase-Locked Receivers

APPROACH

- Stochastic analysis of frequency and polarization diversity
- Evaluation of alternative telemetry strategies
- Simulation of receiver synchronization functions

COLLABORATIONS

- Jet Propulsion Laboratory

RESEARCH SPONSORS

- Jet Propulsion Laboratory

RECENT ACCOMPLISHMENTS

- Analysis of dynamic data rate telemetry
- Analysis of adjacent-channel interference for QPSK carriers
- Design of phase-locked loops with programmable parameters

CASE WESTERN RESERVE UNIVERSITY
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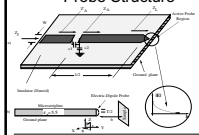
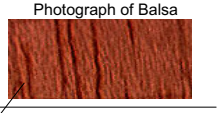
RESEARCH AREAS AND APPLICATIONS

- Nondestructive Super-resolution Imaging and Characterization of Materials at high frequencies
- Design, modeling, simulation, and fabrication of Evanescent Electromagnetic Local Probes (EMP)
- Electromagnetic interactions in semiconductors
- Fiber-optic gas and chemical sensors for harsh environments
- High Frequency and power semiconductor devices
- Quantum Computers

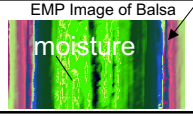
Probe Structure



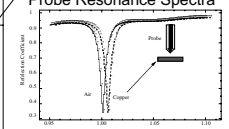
Photograph of Balsa

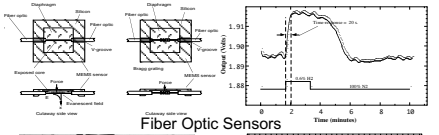


EMP Image of Balsa

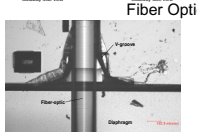


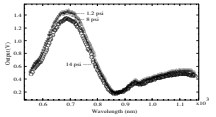
Probe Resonance Spectra





Fiber Optic Sensors





COLLABORATIONS

- Wright-Patterson Air Force Base
- NASA Glenn Center
- NASA/JPL
- Physics Dept.
- Macromolecular Science and Engineering
- Many High-Tech Companies

RESEARCH SPONSORS

- Air Force (Current funding: $290,000)
- Boeing (Current funding: $80,000)
- NASA JPL (Current funding: $135,000)